

EQUIVALENT CARBON ANALYSIS OF THERMAL POWER PLANT

SIDDIQUE MOHAMMED UMAIR

Department of Mechanical Engineering, M.H. Saboo Siddik Polytechnic, Mumbai, Maharashtra, India

ABSTRACT

Equivalent carbon analysis is an approach to analyze the power plant for its exergy destruction and entropy generation rate using a new methodology and concept of equivalent amount of carbon. This paper reviews the conversion of actual exergy at every salient point, exergy lost and entropy generated in joule/ kg by a component of a plant into equivalent amount of carbon in kg. Hence exergy lost due to irreversibility can be converted into exergy equivalent carbon (ExQC), entropy generated can be converted into entropy equivalent carbon (EnQC), ultimately ExQC and IQC will be utilized in order to find the exergetic efficiency, exergetic destruction efficiency, and energy efficiency, carbon emitted by the plant per day and faulty spot which needed to be audited.

KEYWORDS: Exergy, Entropy, Equivalent Carbon, Efficiency and Destruction Rate

INTRODUCTION

The future primary energy mix in 2050 shows that growth rates will be higher for renewable energy sources. In absolute terms, fossil fuels (coal, oil, gas) will remain dominant, up to and including 2050. The share of fossil fuels will be 77% in the Jazz scenario and 59% in the Symphony scenario – compared to 79% in 2010. The share of renewable energy sources will increase from around 15% in 2010 to almost 20% in Jazz in 2050 and almost 30% in Symphony in 2050. Nuclear energy will contribute approximately 4% of total primary energy supply in Jazz in 2050 and 11% in Symphony globally – compared to 6% in 2010 [1]. According to the world survey energy demand present is approximately quadrupled as compared in 1950 [2]. Any system either open or close has energy interaction with the universe [11]. Balancing this interaction is known as energy analysis. Energy analysis is based on the first law of thermodynamics [3]. It is the term ‘energy’ which decides the standard of a country and its development [3]. Present scenario says 80% electricity is extracted from fossil fuel which is going to exhaust one day [3]. Hence there is a need to audit the system in an efficient way in order to utilize the fuel efficiently. It always isn’t possible to find out the faulty spots in the power generating plant by energy analysis. Energy analysis is not the sufficient tool in order to actually locate and find the magnitude of irreversibility [3]. Hence an approach is required in order to tackle the complexity involved in the plant and provide actual auditing area [3].

Before an introduction to exergy analysis is done it is important to understand that heat and work are not energies of same grade. Heat is treated as a low grade form of energy while work is a high grade form of energy [12]. Hence it is impossible to convert the total heat energy into mechanical work [12]. This is second law of thermodynamics. In order to have an accurate analysis both the law should be considered in the analysis [3]. Exergy is a tool which utilizes both the concept. Hence exergy analysis rather than energy analysis is far accurate. It is the parameter which is not always conserved but also destroyed [4]. Exergy analysis has proved the insufficiency of energy analysis when it was first performed in Russia, Europe and Germany [5]. It uses the balance data of mass and enthalpy [5]. It also signifies the

location where the auditing is necessary [5]. Sandya hasti, adisorn aroonwilas [6] performed exergy analysis on ultra super critical power plant, stated that the maximum exergy destruction occurs in the furnaces. P regulagadda, I. Dincer, performed the same on boiler and turbine, stated the faulty spots and gave correct exergetic efficiency [7]. Islam Aljundi [8] performed the same analysis via a different way and found the correct faulty spot. Mr. Santosh mahdeo mistry (Reliance energy manager) [9] presented with technical and financial saving of losses. But it is not necessary that every loss can be saved, there are some losses known as irreversibility [11] which can't be recovered [10]. Balancing the irreversibility in terms of cost is the best way to manage the plant [9]. This irreversibility leads to an entropy rise of the universe which is defined as the ambient temperature times the entropy rise [11] Entropy in general is defined as randomness occurring in the universe due to unavoidable loss [11]. This paper adopts an approach of efficient and feasible utilization of the parameter (temperature, enthalpy, mass flow rate) in order to get the exergy at any point in terms of equivalent carbon. The approach defines exergy at any point in terms of exergy equivalent carbon. Entropy rise at any point in terms of entropy equivalent carbon. Irreversibility in terms of irreversible equivalent carbon. This paper will utilize the ExQC, IQC, and EnQC in order to determine exergetic and exergetic destruction efficiency. Furthermore, this paper will give an idea regarding the carbon emission associated with the plant and taking into consideration the protocols signed, it can also speak about the probability of carbon trading and marketing.

NOMENCLATURE

m – Mass flow rate of flue gas in kg /kg of fuel

C_p – Specific heat of flue gas approx 0.23 Kcal /kg⁰c

GCV – Gross calorific value of coal in Kcal /kg

M – Kg of moisture in 1 Kg of coal

C_{ps} - Specific heat of superheated steam approx 0.45Kcal /kg

H_2 - Amount of H_2 in Kg /Kg of coal

AAS – Actual mass of air supplied /Kg of fuel

$EA = O_2 \% / (21 - O_2 \%)$

C - % of carbon per kg of coal

O_2 - Amount of oxygen per kg of coal

S – Amount of sulphur per Kg of coal

m_{ash} - Total fly ash collected per Kg of fuel burnt

$m_{bt/ash}$ - Total ash collected per Kg of coal burnt

$CO\%$ - Volume of flue gas leaving the economizer

$CO_2\%$ - Actual volume of CO_2 in flue gas

METHODOLOGY

Working with a power plant proves difficult to analyze the using exergy model, though, exergy is the most

accurate and prominent way of calculating power plant. The paper reviews a technique of equivalent carbon according to which exergy at every point in plant can be actually expressed in terms of mass of carbon called equivalent carbon. Equivalent carbon is defined as the amount of carbon of assumed calorific value required to be burnt in one second so as to produce equivalent amount of exergy for which it is set as equivalent. Exergetic equivalent carbon ExQC is defined as amount of carbon to be burnt in one second so as to produce the required amount of exergy, entropy equivalent carbon EnQC is amount of carbon required to be burnt in one second so as to produce the same entropy rise. Irreversible equivalent carbon IQC is amount of carbon burnt to produce same heat as produced in irreversibility, it is generally given as difference between two ExQC. In order to calculate exergetic efficiency of a plant exergy at every point in layout of plant is first calculated using balance of mass flow rate and temperature [6] converted into ExQC, corresponding IQC will be the difference. Here exergetic destruction efficiency is defined as the ratio of IQC to ExQC in and exergetic efficiency is defined as the ratio of ExQC out to ExQC in.

PARAMETER STUDY

In order to determine efficiency temperature and pressure are the essential terms at every salient points of the plant

- Inlet and outlet temperature, enthalpy, entropy to every component
- Mass flow rate of steam at every critical point (e.g. boiler inlet, outlet, condenser inlet..... Etc)
- Specific heat of steam at every point
- Exergetic, energetic efficiency
- Content of coal (% hydrogen, % carbon, % sulphur, % oxygen, % moisture, % ash).
- % of oxygen and carbon dioxide in flue gas per kg of coal
- Flue gas temperature
- Ambient humidity factor(kg/ kg of dry air)
- G. c. v of coal(kcal/ kg)
- %combustible present in ash(sample of ash will also do)
- G. c. v of ash (kcal/ kg)
- Temperature of ash
- Mass flow rate of dry flue gas/ kg of fuel
- Amount of moisture/ kg of coal
- Theoretical air requirement for combustion of 1kg of fuel
- % oxygen in flue gas/ kg of coal
- Ambient temperature, enthalpy, entropy

- Mass flow rate of coal
- Mass flow rate of flue gas
- Amount of ash collect in kg/ kg of fuel
- G.c.v of fly ash
- G.c.v of bottom ash
- Overall friction factor

Parameters mentioned are used in calculating the losses which can be converted into corresponding IQC.

MATHEMATICAL EQUATIONS

In order to calculate ExQC, EnQC and IQC consider following relationship. ExQC is defined as amount of carbon required to be burnt in one second in order to produce the corresponding amount of exergy. Hence known as exergy equivalent carbon. $\text{ExQC} = (\text{Exergy in KJ/Kg}) \times (\text{time}) / (\text{calorific value})$. EnQC is defined as the amount of carbon required to be burnt in one second in order to produce the corresponding amount of entropy. Hence known as entropy equivalent carbon. $\text{EnQC} = (\text{Entropy in KJ/KG-K}) \times (\text{time}) / (\text{calorific value})$. IQC is defined as the amount of carbon required to be burnt in one second in order to produce the corresponding amount of irreversibility. $\text{IQC} = (\text{Difference in exergy}) \times (\text{time}) / (\text{calorific value})$. The paper utilizes the following losses occurring in the plant to convert into respective equivalent carbon

Loss of heat due to dry flue gas

Loss of heat due to moisture in fuel and combustion air

Loss of heat due to combustion of hydrogen

Loss of heat due to radiation

Loss of heat due to UN burnt

Loss of heat due to incomplete combustion

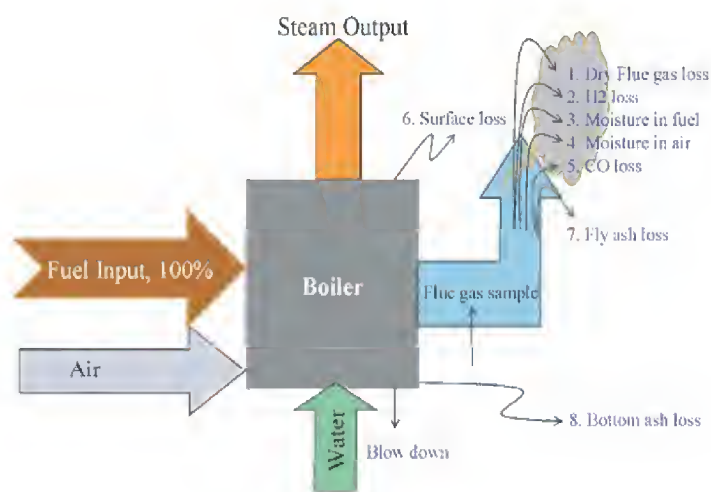


Figure 1: Layout of Losses Occurring in Boiler

Basic derived parameter necessary for calculation

$$EA = O_2\% / (21 - O_2\%) [10]$$

$$\text{Theoretical air required} = \{(11.6 \times C) + (34.8 (H_2 - O_2 / 8) + (4.35 \times S))\} / 100 [10]$$

$$AAS = (1 + EA/100) \times \text{theoretical air} [10]$$

Following models gives the fraction of heat loss taking place in boiler

$$\text{Loss due to dry flue gas} = m \times C_p \times (T_f - T_a) / \text{G.C.V of fuel} [10]$$

$$\text{Loss due to evaporation of moisture in fuel} = M \times (584 + C_{pf}(T_f - T_a)) / \text{G.C.V of fuel} [10]$$

$$\text{Loss due to evaporation of water in fuel} = 9 \times H_2 \times (584 + C_p(T_f - T_a)) / \text{G.C.V of fuel} [10]$$

$$\text{Loss due to moisture in air} = AAS \times \text{humidity factor} \times C_p \times (T_f - T_a) / \text{G.C.V of fuel} [10]$$

$$\text{Loss due to UN burnt in fly ash} = (m_{\text{ash}} \times \text{G.C.V of fly ash}) / \text{G.C.V of fuel} [10]$$

$$\text{Loss due to UN burnt in bottom ash} = (m_{\text{bt/ash}} \times \text{G.C.V of bottom ash}) / \text{G.C.V of fuel} [10]$$

$$\text{Loss due to incomplete combustion} = \{CO \times C \times 5744\} / \{(CO + CO_2) \times \text{G.C.V of fuel}\}$$

Above models are utilized to calculate Irreversible equivalent carbon

$$IQC = (\text{loss in KW} \times \text{time of combustion}) / (\text{Calorific value})$$

Hence exergy efficiency and exergetic destruction efficiency is expressed as,

$$\eta_{\text{exergy destruction}} = (\text{Total IQC}) / (\text{ExQC in}).$$

$$\eta_{\text{exergy}} = 1 - \eta_{\text{exergy destruction}}.$$

Efficiency calculated using this approach can be validated against practical efficiency.

CONCLUSIONS AND FURTHER SCOPE

This paper defines a new type of efficiency called equivalent carbon efficiency almost equivalent to exergetic efficiency. Using this method one can summaries the plant in terms of carbon flow and judging the performance of each component becomes easier. The concept can be further used in expressing the plant flow exergy in terms of Indian currency of money, which can be used to maximize the net output profit of the plant at the advantage of hike and fall of price of coal and electric power, by achieving an optimize or maximum profit relationship between the considered variables.

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